Psychophysiological Arousal and Craving in Smokers, Deprived Smokers, Former Smokers, and Non-Smokers

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Abstract. This study investigates the biometric signature associated with tobacco craving and stress elicitation using principles of cue reactivity. Seventy-five non-smokers and smokers (half of whom were tobacco-deprived for 6 hours) took part in a standardized laboratory session during which they were presented with a series of film clips designed to arouse fear, amusement, or craving. Participants self-reported their emotional response to each film clip and wore non-invasive biosensors to collect physiologic data. Findings indicate different patterns of physiologic arousal for smokers than non-smokers; and that among smokers, deprived smokers had significantly different arousal patterns than non-deprived smokers. This article describes how the elicitation of stress and craving can contribute to the prediction of arousal patterns associated with tobacco craving and how this can create new opportunities for smoking cessation intervention. A comparison of each group's patterns of arousal and physiologic activity is presented, with particular focus on the differences between smokers and deprived smokers.

Keywords. smoking, psychophysiology, biosensors, cue reactivity

Introduction

Craving plays an important role in the maintenance of substance use, including cigarette smoking [1]. Cravings reflect the activation of motivational systems that have particular response patterns involving self-report, behavioral, physiological, and cognitive aspects [2]. The craving to smoke tends to increase particularly in the presence of smoking-related cues [3]. Previous studies of smokers have confirmed a positive relationship between exposure to smoking cues and measurable changes in subjective and physiological responses [e.g., 4]. The current study uses principles of cue exposure and non-invasive sensors to investigate the biometric signature associated with tobacco craving and arousal elicitation [5]. A cue exposure presentation was created using film clips to demonstrate positive and negative stress associated with emotional cues and cigarette smoking. Film clips were chosen as a cue-exposure tool due to their success in invoking arousal in the laboratory [6].

Wearable sensors allow for the non-invasive collection of individualized, biometric data that promise to enhance our understanding of emotional, physiological,

and behavioral responses [7, 8]. In this study, biosensors were used to facilitate the collection of physiological data and response patterns in groups of smokers in naturalistic and laboratory settings. Comparisons of physiological responses to arousal and tobacco craving between smokers and non-smokers may enable researchers to differentiate arousal patterns associated with stress reactivity and craving.

This study included three phases. Phase 1 consisted of collecting continuous biometric data for 3 days using an armband sensor. In Phase 2, an experimental session was carried out in which arousal was measured through cue reactivity. In the third phase, physiological arousal patterns were identified. Statistical algorithms are presently being developed to accurately predict the arousal patterns of tobacco use and smoking behavior.

1. Method

1.1. Participants

Human subjects' approvals were obtained from the local institutional review board at the University of Hawaii and the United States Army and Materiel Command's Human Subjects Research Review Board (HSRRB). Recruitment took place in the local university community between April and September 2008. Information regarding the study was disseminated through flyers and classroom presentations, as well as public service announcements in the student newspaper and on the campus radio station. Inclusion criteria required participants to be at least 18 years old, fluent in English, and not undergoing any form of Nicotine Replacement Therapy for smoking cessation. Individuals were excluded if they reported any smoking-related health conditions, and/or required prescription medication that could affect the study results (e.g. hypertension, anxiety disorders, asthma, etc.). Based on their smoking history, eligible participants (N=75) were identified as non-smokers (*n*=23); former smokers (*n*=23); or current smokers (*n*=29). Former smokers were classified as those who had quit smoking at least 6 months prior to recruitment. Current smokers were defined as those who smoked a minimum of 10 cigarettes a day, and scored a 5 or higher on the Fagerström test for nicotine dependence. Smokers were randomized into 1 of 2 conditions — non-deprived (*n*=14) or deprived *(n*=15*).* During the study, deprived smokers were requested to refrain from smoking for 6 hours, while non-deprived smokers continued with their normal smoking routine.

1.2. Materials and Measures

1.2.1. Self-report Measures

Following informed consent procedures, participants completed a standard demographics form, as well as three baseline questionnaires (Smoking History and Behavior, Situational Self-Efficacy, and a Questionnaire on Smoking Urges). Two additional questionnaires were also administered at follow-up (Self-Assessment Manikin and ITC-Sense of Presence Inventory), with the Questionnaire on Smoking Urges being provided both at baseline and follow-up.

1.2.2. Physiological Measures

A BodyMedia® SenseWear® PRO_2 armband was worn on the upper-right tricep for 3 days to measure each participant's biometrics in a natural setting. The armband collected a variety of physiologic data including heat flux (HF), skin temperature (SkT), galvanic skin response (GSR), energy expenditure (EE), and movement. Additional physiological data were collected during the experimental session using Thought Technology's ProComp Infiniti System in conjunction with Biograph Infiniti 3.1 software. Three Thought Technology sensors collected heart rate (HR), blood volume pressure (BVP), and respiration rate (RR). The armband was also worn during the experimental session in order to synchronize the participant's physiological arousal to the film stimuli.

1.2.3. Procedure

During Phase 1, participants wore the SenseWear® PRO_2 armband for 3 consecutive days to allow the monitoring of their biometric data outside of the lab setting. Smokers in the study were instructed to continue their normal smoking routines while wearing the armband, but to press a time stamp button each time they smoked a cigarette. This button recorded an annotation on the raw data so that smoking could be correlated with a physiological outcome. Never smokers and former smokers also wore the armband for 3 days, but were not required to press the time stamp button at any point during the monitoring. Before attending the experimental session in Phase 2, deprived smokers were asked to refrain from smoking for 6 hours. The experimental session was structured to include: a) a calibration phase; b) a stress elicitation activity (the expectation of public speaking) to collect baseline arousal levels; and c) a cue exposure presentation. The film presentation consisted of 12 validated film clips that elicited one of 3 types of arousal — fear, amusement, or craving — and 13 neutral clips alternating between experimental clips to eliminate delayed response patterns [9]. At the completion of each film clip, participants were asked to rate their arousal levels (e.g. select a specific emotion, valence, and intensity). Conducting a standardized stress event in the laboratory enabled the comparison of groups of smokers on their psychological interpretations of arousal.

1.2.4. Data Analysis

Simple descriptives were employed in Phase 3 to determine sample characteristics. Analysis of Variance (ANOVA) and cross-tabs were used to determine whether there were significant differences between the assigned groups. A 4 (group) x 5 (type of arousal) factorial Multivariate Analysis of Variance (MANOVA) was used to detect significant mean differences between the four groups using physiologic variables as the dependent variables and group assignment and type of film clip as independent variables. Standardized T-scores were used (M=50, SD=10), to allow comparison between variables with different measurement units. Follow-up ANOVAs and *post hoc* tests were used to further explore main effects and interaction effects, as appropriate. Crosstabs were used to explore group differences in the self-reported arousal following each film clip.

2. Results

Average age of the participants was 33.8 years (*SD*=12.6, range=19-65). The sample was 56% female; White (53%) or Asian (29%); unmarried (81%); and in good/very good health (79%). There were no significant demographic differences between the groups, except for age (F(3,73)=4.53, $p<.05$), where former smokers were found to be significantly older (M_{FS}=41.1) than non-smokers and smokers (M_{NS}=30.6; M_S=30.7).

Homogeneity of variance was violated for these analyses (Box's M=23842.7, $p<.001$). Several transformations to the data were attempted, but none were able to resolve the homoscedasticity. As a result, care must be taken when interpreting these results. Main effects were found for both group assignment (Wilks' $\lambda=.53$, $p<.05$) and type of film clip (Wilks' $\lambda=.78$, $p<.05$). A significant interaction (Wilks' $\lambda=.95$, $p=.91$) prompted further analysis. Follow-up ANOVAs explored mean differences between all possible interaction combinations. A Bonferroni correction was used in order to avoid inflation of the Type 1 error rate. Significant mean differences were found for the interactions on 8 of the 10 physiologic variables ($p<.01$, η^2 range=.01 to .26), with only EKG and EE being non-significant. Follow-up *post-hoc* tests on the fear, amusement, and craving film clips found 56 of a possible 144 comparisons with significant differences between non-smokers, former smokers, smokers, and deprived smokers across conditions. Smokers were significantly different from deprived smokers in their physiologic arousal to fear, amusement, and craving — with GSR and RR significantly different across all 3 conditions. Never smokers were significantly different from all other groups in their physiologic arousal to fear, amusement, and craving — with SkT, movement, and BVP significantly different across all 3 conditions. Former smokers behaved more similarly to smokers than to never smokers — with SkT, movement, BVP and RR significantly different from never smokers across the 3 conditions.

Overall ratings on the self-report questionnaires found that most participants matched their emotion to the intent of the film clip: 86.7% rated the neutral clips as calming or neutral; 91% rated the amusement clips as funny; and 75% rates the fear clips as scary or anxiety-provoking. Among smokers, 45% indicated craving a cigarette after watching a smoking clip; however, crosstabs determined that deprived smokers reported "craving a cigarette" 1.67 times more often than non-deprived smokers. Deprived smokers were 1.27 times more likely to report feeling anxious after a fear clip, and 1.43 times more likely to report feeling happy after an amusement clip. Neither the reported intensity nor the valence of emotions was significantly different between the two groups of smokers.

3. Discussion/Conclusion

Recording stress and arousal patterns in a laboratory setting has allowed the differentiation of response patterns between non-smokers, former smokers, current smokers, and deprived smokers. While several arousal patterns were similar across groups, real differences in physiological arousal were evident among deprived and non-deprived smokers. For example, GSR and RR were significantly higher when smoking stimuli were presented to deprived smokers. Therefore, it appears that GSR and RR may be important channels for understanding the way in which craving is expressed. Not only were physiological differences apparent between smokers and deprived smokers, but their subjective responses varied as well.

Another area with interesting implications is the finding that former smokers behaved more similarly to smokers than to non-smokers. This may imply differences in the. Further comparisons between former smokers and current smokers will allow a better understanding of the physiological aspects of craving behavioral and cognitive aspects of behavior change during smoking cessation associated with cessation and relapse. This is important, as the risk of relapse is known to be the most difficult aspect of addiction treatment [10]. These initial findings are being used to build a foundation for further analysis of the data and for refining predictive algorithms.

As data from this study continues to be analyzed, the focus will shift away from group comparisons to concentrate more acutely on individual and unique patterns of physiological arousal. Sensors offer new potential for capturing dynamic physiologic data that can be used to develop medical technologies and cessation interventions with tailored, personalized feedback based on individual response patterns [11]. Having the knowledge to understand and predict arousal and craving at an individual level promises improved interventions at all levels of addiction. This research aims to improve our understanding of the psychophysiology of craving and addiction and offers the interdisciplinary scientist a clearer direction from which novel treatment approaches and innovative medical technologies might develop.

References

[1] J.D. Killen, and S.P. Fortmann, Craving is associated with smoking relapse: Findings from three prospective studies, *Experimental and Clinical Psychopharmacology* **5** (1997), 137-142.

[2] M.A. Sayette, C.S. Martin, J.G. Hull, J.M. Wertz, and M.A. Perrott, The effects of nicotine deprivation on craving response covariation in smokers, *Journal of Abnormal Psychology* **112** (2003), 110-118.

[3] B.L. Carter and S.T. Tiffany, Meta-analysis of cue-reactivity in addiction research, *Addiction* **94** (1999), 327-40.

[4] S.B. Baumann and M.A. Sayette, Smoking cues in a virtual world provoke craving in cigarette smokers, *Psychology of Addictive Behaviors* **20** (2006), 484-489.

[5] L.W. Jerome, P.J. Jordan, and N. Faraj, Evaluation of group performance in a mediated environment, *Annual Review of CyberTherapy and Telemedicine* **4** (2006), 117-126.

[6] D.M. Sloan, Emotion regulation in action: emotional reactivity in experiential avoidance, *Behavior Research and Therapy* **42** (2004), 1257-1270.

[7] N. Badler, J. Allbeck, and R. Bindiganavale, Describing human and group movements for interactive use by reactive virtual characters, Paper presented at the 23rd annual Army Science Conference, Orlando, FL, 2001.

[8] R.W. Picard, Affective medicine: Technology with emotional intelligence. MIT Media Laboratory, 2001. Accessed 21 November 2007, from: http://vismod.media.mit.edu/tech-reports/TR-537.pdf.

[9] J. Rottenberg, R.R. Ray, and J.J.Gross, Emotion elicitation using films, in J.A. Coan, and J.J.B Allen (Eds.), *The handbook of emotion elicitation and assessment*, Oxford University Press, New York, 2006.

[10] C.P. O'Brien, A range of research-based pharmacotherapies for addiction, *Science* **278** (1997), 66-70.

[11] P.J. Jordan, L.W. Jerome, and N. Faraj, Physiological and momentary assessment for identifying tobacco use patterns, *Annual Review of CyberTherapy and Telemedicine* **4** (2006), 95-102.